



U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

Chapter 10

THE GENERATOR, EXCITER, AND VOLTAGE REGULATOR

Learning Objectives

As a result of this chapter, you will be able to:

1. Describe the functions of the control systems in starting, running, and shutting down the diesel engine.
2. Describe the various parameters to be monitored in order to ensure proper operation of the engine and generator.
3. Explain how the engine controls sense essential engine parameters and control these in operation of the engine.

Learning Objectives (continued)

4. Identify the key components of the engine protection system and state the purpose or describe the function of each.
5. Recognize various control components of this system, how they are put together, and the various ways they could fail.
6. Recognize signs of component deterioration, impending failure, or actual failure.
7. Explain generator loading onto the engine.

Emergency Diesel Generator control systems are designed to:

- Start the engine automatically in response to an accident signal and accelerate to rated speed.
Overrides manual control unless locked out.
- Flash the generator field and come up to proper frequency and voltage within 10 seconds.
- Close the output circuit breaker onto its associated de-energized class 1E bus.

Emergency Diesel Generator control systems are designed to... (continued)

- Initiate sequencing of accident loads onto the bus.
- Control EDG speed and voltage within acceptable ranges to power accident loads.
- Permit manual control during surveillance testing and maintenance.
- Shutdown the EDG unit to protect it.

Protective shutdowns required during ESF (generic plant):

- Engine Overspeed
- Generator Differential Fault
(Reference Chapter 9 discussion).

Other ESF trips allowed with co-incident logic
and individually alarmed, testable sensors:

- Generator current - high
- Lube oil - low pressure
- Crankcase - high pressure
- Jacket water - high temperature
- Generator - low voltage

Typical additional protective shutdowns during surveillance testing:

- Generator - reverse power
- Loss of Generator Field
- Jacket water - low pressure
- Lube oil - high temperature
- Room's fire alarm
- Others (plant options)

EDG controls and instrumentation provide:

- Both automatic and manual controls for starting, acceleration, speed-frequency control, voltage control, and output circuit breaker closing-opening.
- Sensing devices for critical parameters with visual monitoring readouts, alarms, and trips.

The following two slides depict typical diesel engine temperatures and pressures during operation.

EDG Engine Parameters Monitored (Typical Value Ranges are Indicated)

ENGINE TEMPERATURES:

- Individual Cylinder Exhaust Temps 600 to 1200 °F
- Pre-Turbo Exhaust Temps 500 to 800 °F
- Cooling (Jacket) Water Temp – Out 140 to 185 °F
Inlet is typically 8 to 10 F cooler
- Lube Oil Temperature – Out 160 to 215 °F
Inlet is typically 20 to 30 F cooler
- Inlet Manifold (post intercooler) 110 to 150 °F

EDG Engine Parameters Monitored (continued)

ENGINE PRESSURES:

- Lube Oil to Engine or LO Header 30 to 80 psig
- Water Pump(s) Pressure 20 to 50 psig
- Fuel Oil Pressure to Header 20 to 30 psig
- Air Manifold Pressure
 - Blower Scavenged 4 to 8" H₂O
 - Turbocharged (at full load) 15 to 30 psig

For other parameters that may be monitored under various operating modes or conditions, see the Tables in Section 10.4 of the Student Manual.

Engine Control Circuitry

A typical EDG Starting Circuit is illustrated in Figures 10-1 to 10-3.

- Figure 10-1 shows the starting portion of the circuitry. This is typically duplicated for redundancy.
- Figure 10-2 shows the speed monitoring and stopping portion of the circuitry.
- Figure 10-3 shows the monitoring portion of the circuitry including coincident logic for the lube oil pressure shutdown monitoring.

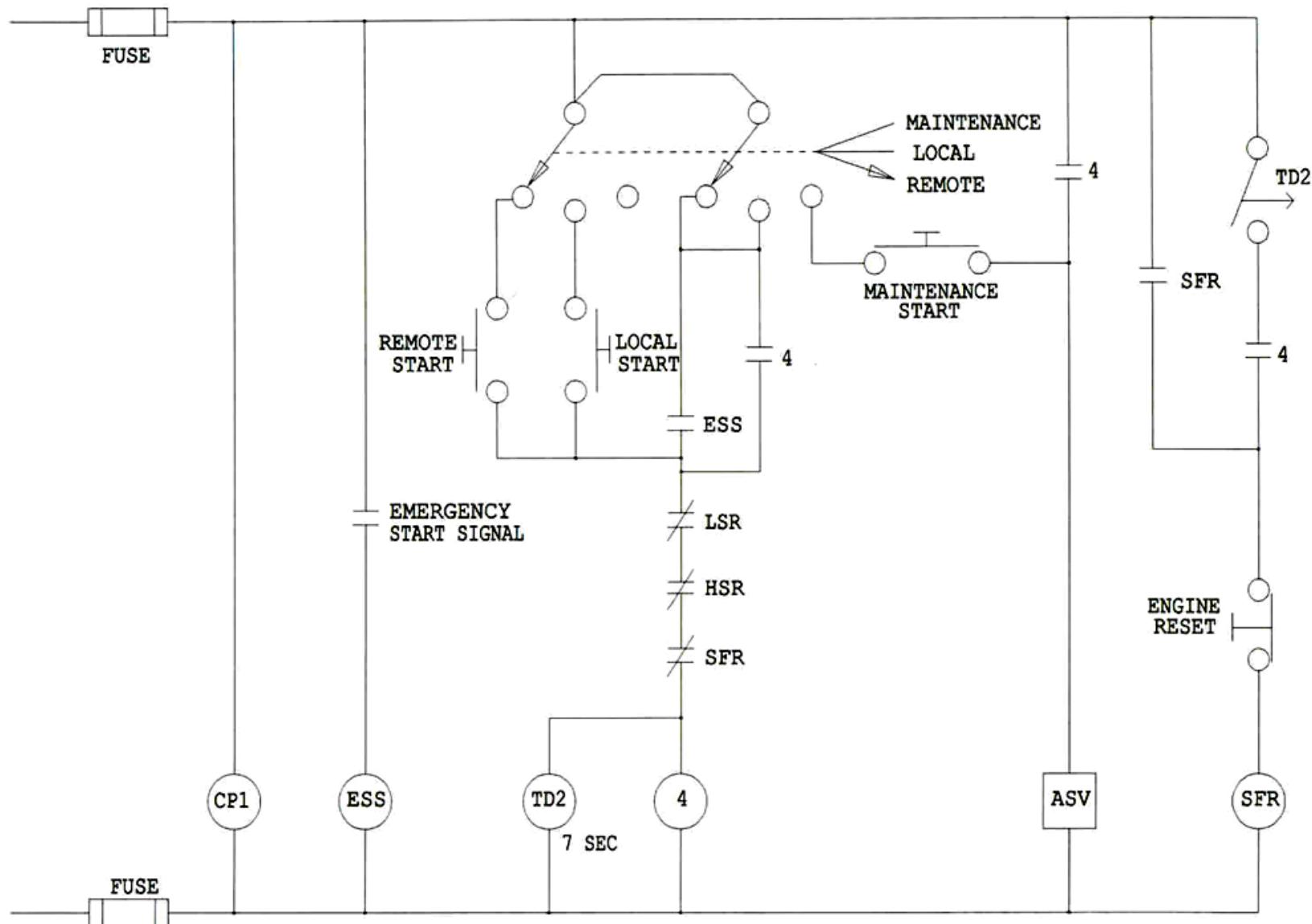


Figure 10-1 Starting Circuitry -- This circuit is often duplicated, for redundancy

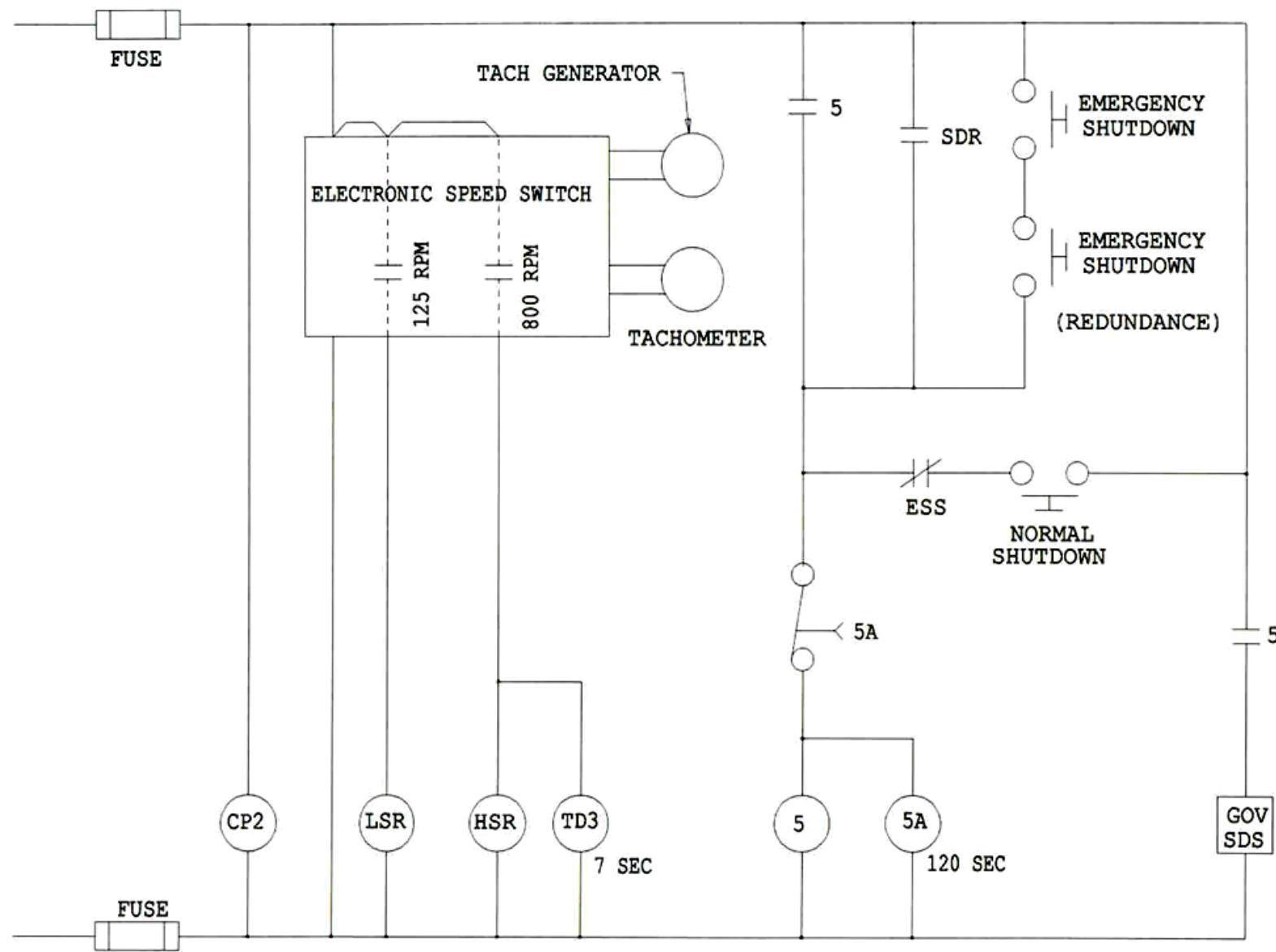


Figure 10-2 Speed Monitoring and Stop Circuitry

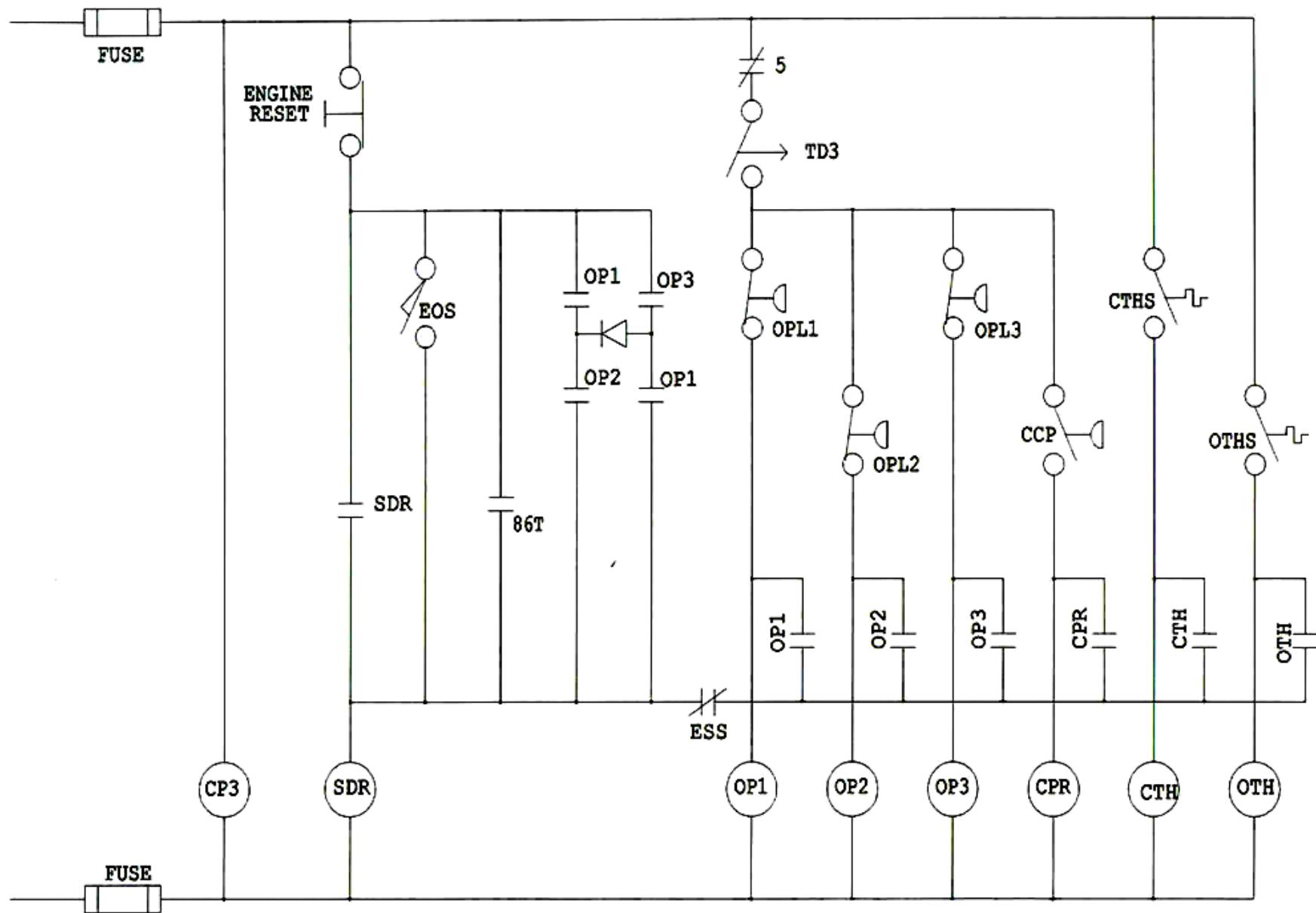


Figure 10-3 Fault Shutdown and Monitoring Circuits

DIGITAL Instrumentation and Controls

Almost everything that you can do with analog devices you can do with digital devices. We can break digital devices down into three general categories:

- Discrete Devices
- Programmable Control Devices, including computer systems
- Restricted programming devices.

DIGITAL I & C -- Discrete Devices

Discrete devices would include such things as meters that read out in Alphanumeric display rather than a needle pointing to a value on the meter face. Such would include (but not be restricted to):

- Volts, Amps, Watts, KVAR, Frequency, Speed
- Pressure, Temperature, Flow, Valve Position, etc.

Such instruments take the basic system parameter, convert it to a digital value, scale it, and mathematically manipulate the value to convert it to a digital display, though in many cases, an analog may also be displayed such as an advancing LED line display.

If the scaling is not done properly, a digital display may in fact be less accurate than an analog display.

DIGITAL I & C -- Discrete Devices (continued)

Digital devices (meters) are not always appropriate for all uses.

- For instance, tuning a governing system. In this case, we want to see what the voltage to the actuator is doing, not that it is a specific exact value. We want to see if it is oscillating and if so, is it fast or slow, large or small...

A digital meter has a sampling time (maybe 1 reading/second), to keep the meter from dithering. If the voltage is oscillating at a different rate, the digital meter will show an ever-changing reading which cannot be interpreted.

- The same principle applies in tuning the voltage regulator or any other controlling instrument.

DIGITAL I & C – Programmable Control Devices

Programmable Control devices break down into two general types – general computers, and dedicated computers.

- Computers – may receive and analyze data and manipulate and display input and control outputs.
To do so, input and output modules are required to convert the field data to digital format (0 or 1 or dividing the input into bits or words).
- Programmable Logic Controls (PLC), which generally include the necessary input and/or output modules. The PLC is specifically made for control applications. We will concentrate on the PLC as the primary control system.

DIGITAL I & C – Programmable Control Devices - 2

- A PLC can be connected to other computers so that data within the PLC can be forwarded to or received from other PLC's or remote computers.
- Monitors on such computers can display tables of values, system or process diagrams, alarm and shutdown status and so forth.
- CAUTION: When a computer system is connected to a PLC controlling an EDG, special provisions must be made to guard against a computer, computer virus, and/or unauthorized entry being able to influence the controlling PLC. In other words, the PLC should be in control with data going from it, but restricted from coming to it.

DIGITAL I & C – Programmable Control Devices - 3

- PLC's are generally programmable through either a connection to a computer (with special software) or a Hand Held Programming Module.
- They typically program in Ladder Logic. Date and files may be printed out for record purposes and to help in troubleshooting problems.
- High end PLC's also contain PID loop capability and can control operating parameters, such as water temperature, air manifold temperature, etc.
- Need backup parts and good electronic technicians to cope with problems. Interface/modules are more likely the problem than the PLC or its software.

DIGITAL I & C – Restricted Programmable Control Devices

- This classification would include devices such as the Woodward 2301D or 723 governing systems. These are programmed using special software and/or a hand held programming device. There are only certain variable that can be changed.
- Once adjustments are made and the programmer is removed, the operating parameters can only be changed by again connecting the programming device.
- Some devices, such as the DRU, provide potentiometer settings and/or internal switches, that can be used to make small adjustments to the operating parameters.
- A few systems include EEPROM's that save the program within the device.

DIGITAL I & C – Programmable (Source) Code

- There is some concern about the programming (source) code used in digital devices and the code's security. NRC has been rather hesitant about use of digital devices without a record/copy of the source code.
- In the case of PLC, the top end source code (the ladder diagram) is generally available to be printed out and/or electronically saved.
- More deeply embedded code is generally considered to be proprietary by the vendor and will generally not be released.
- Reasons behind not releasing the source code are:
 - Protection of Property Rights
 - To ensure unknowing persons cannot make changes to the code that would cause equipment to malfunction, putting the vendor in jeopardy for loss of function, property damage, injury, or loss of life.

EDG Responses to Load Changes

Typical EDG voltage and frequency transient responses are illustrated in Figures 10-4 and 10-5.

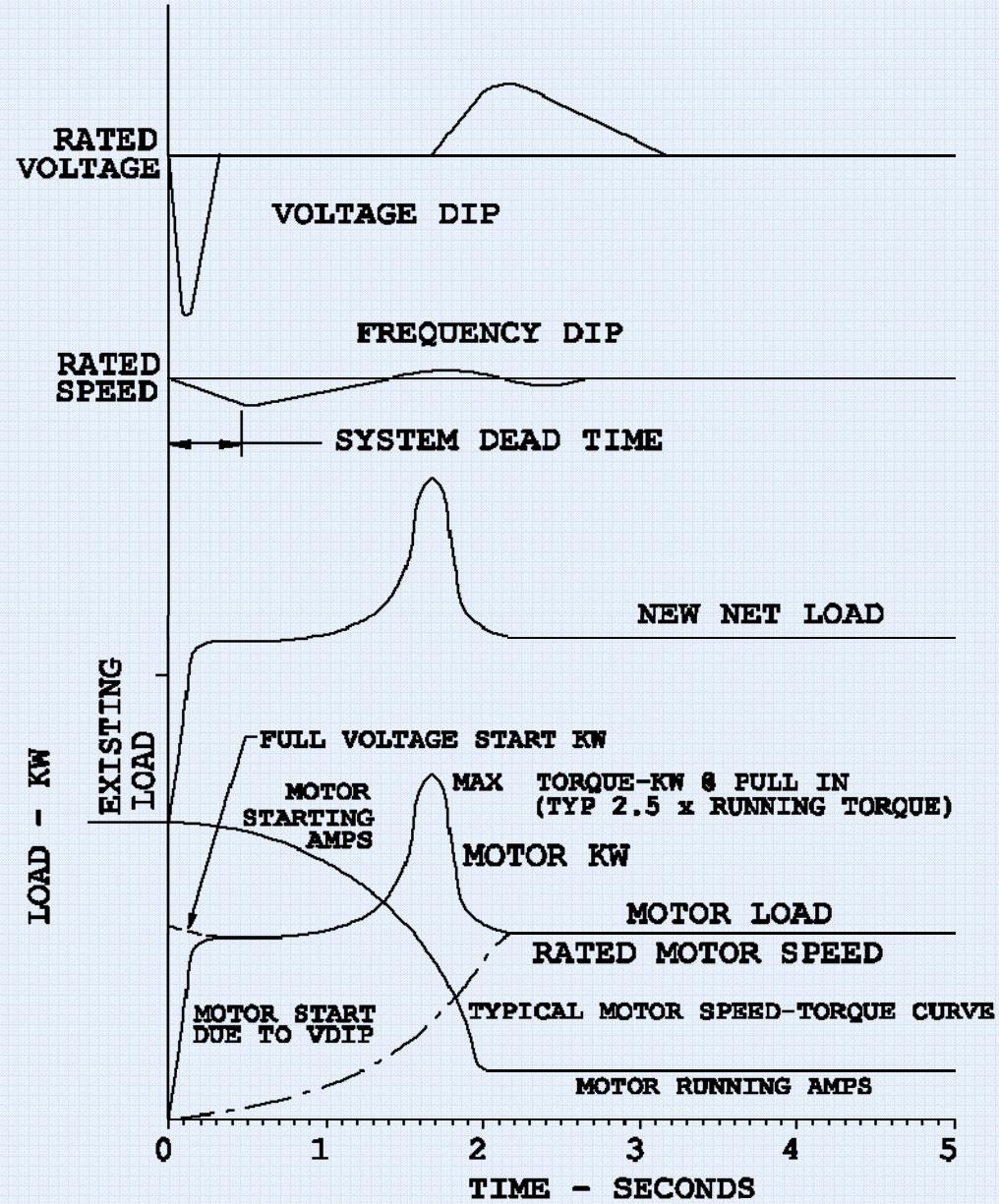


Figure 10-4
Motor
Starting Load

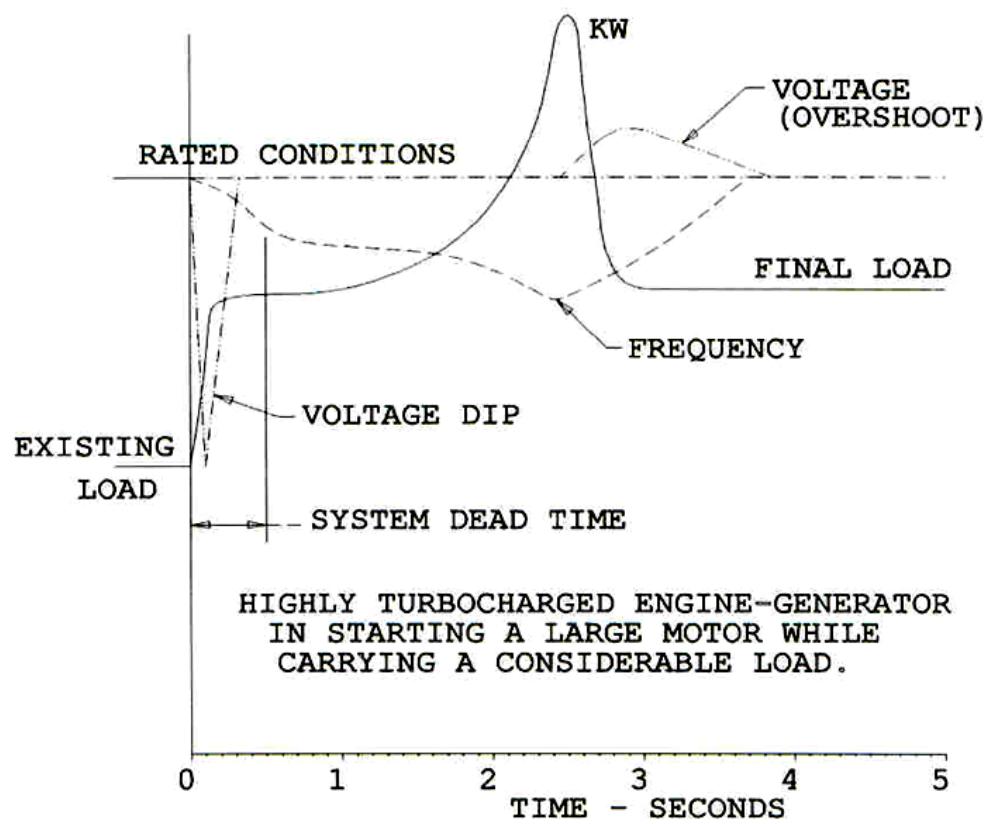
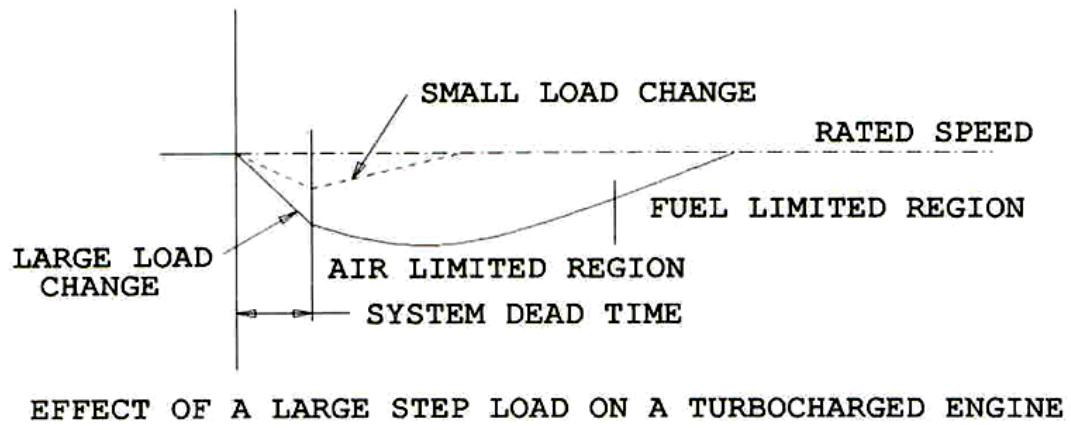


Figure 10-5
Typical Loading Situation

END OF CHAPTER 10

